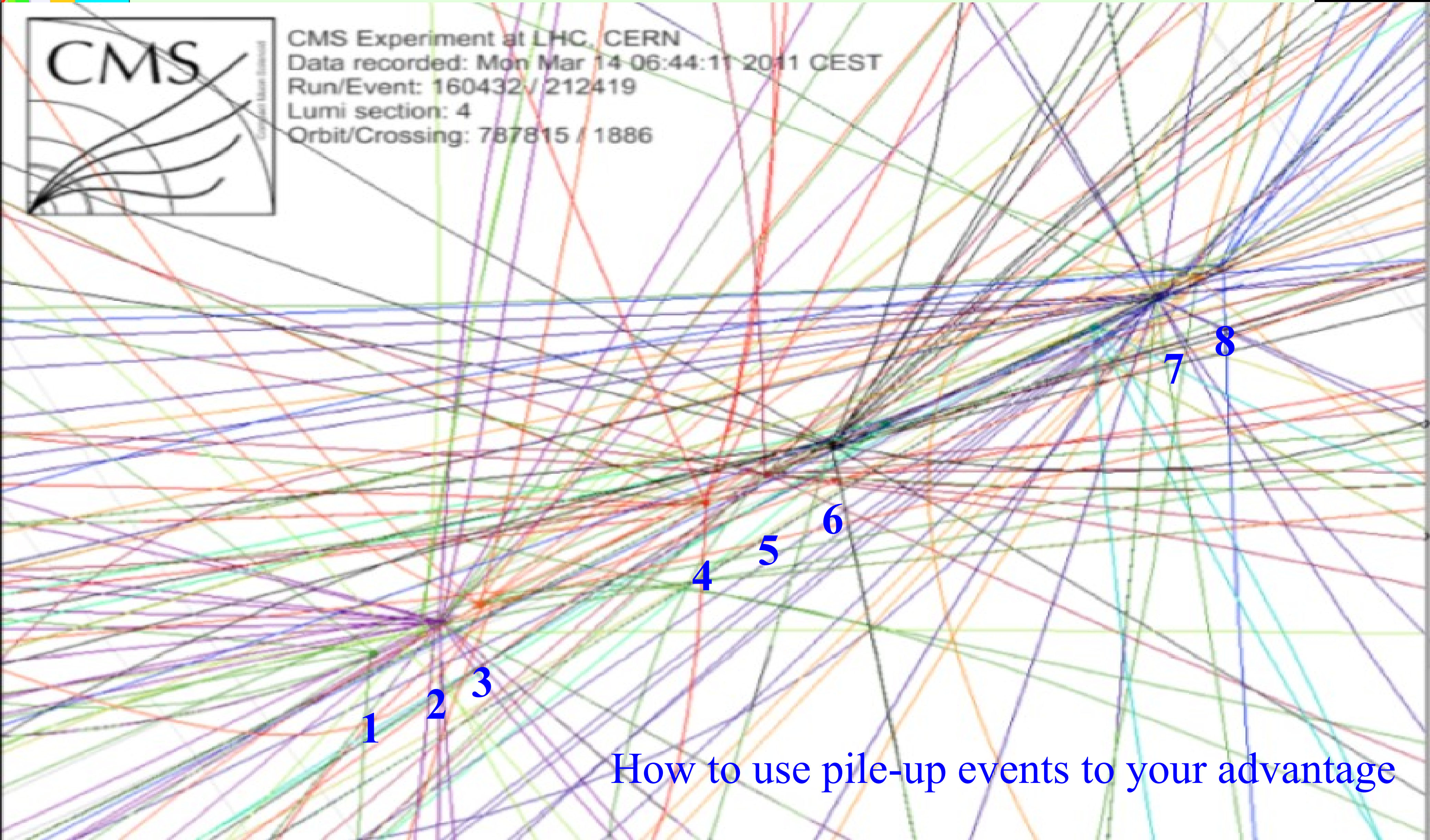
"Measurement of the pp inelastic cross section using pile-up events with the CMS detector"



Analysis technique

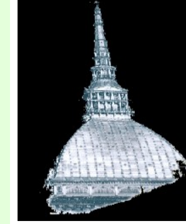
The probability of having n_{pileup} depends only on the total $\sigma(pp)$ cross section:

$$P\,(n_{Pileup}) = \frac{(L*\sigma)^{n\_pileup} * e^{-(L*\sigma)}}{n_{pileup}!}$$

If we count the number of pile-up events as a function of luminosity, we can measure $\sigma(pp)$.

For an accurate measurement we need a large luminosity interval.

Steps



1. Acquire the bunch crossing using a primary event:
   the bunch crossing is recorded because there was an event that fired the trigger.
   We don't use this primary event, we only use it to record the bunch crossing

2. Count the number of pile-up events:
   for any give bunch crossing, we count the number of vertices in the event.

3. Correct the number of visible vertices for various effects:
   vertex merging, vertex splitting, real secondary vertices…

4. Fit the probability of having $n = 0,\ldots.8$ pile-up events as a function of luminosity:
   using a Poisson fit, we obtain 9 values of $\sigma(pp)_n$

5. Fit the 9 values together:
   from $\sigma(pp)_n$ we obtain $\sigma(pp)$

Luminosity and pile-up events

LHC is doing really well, it has reached a record instantaneous luminosity of $1.7*10^{33}$ cm^{-2} s^{-1}. However for this study the important parameter it the instantaneous luminosity per bunch (currently 1080 bunches)

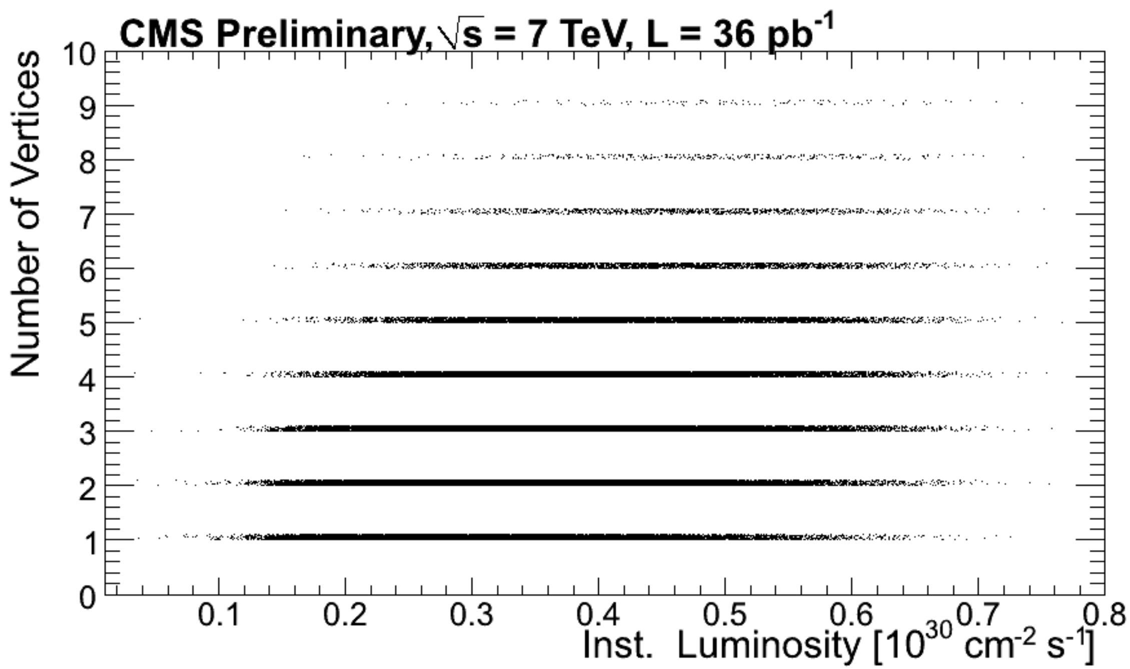
We studied events with:

0-8 pile-up events

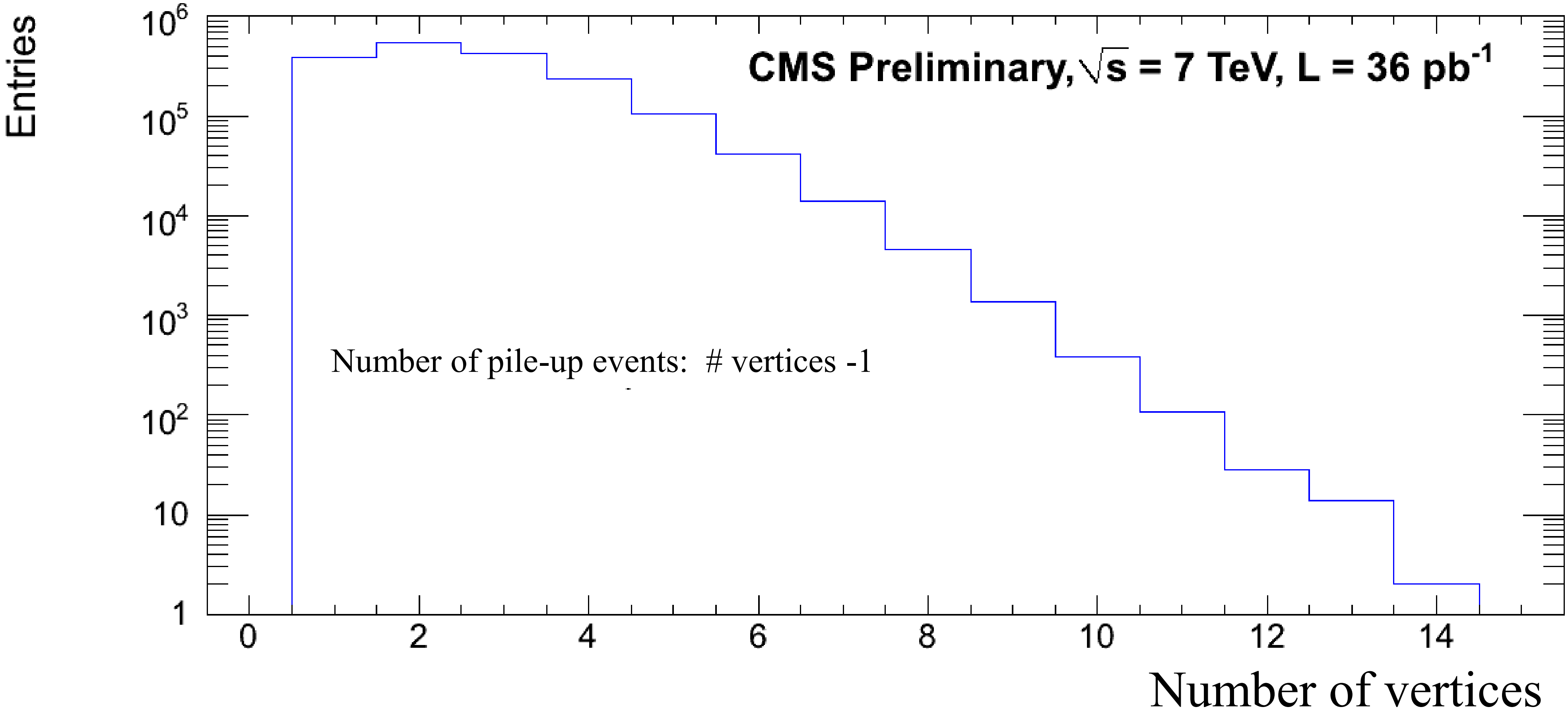
and

luminosity range 0 - 0.7 10^{30} cm^{-2} s^{-1}

(2010 data taking period)



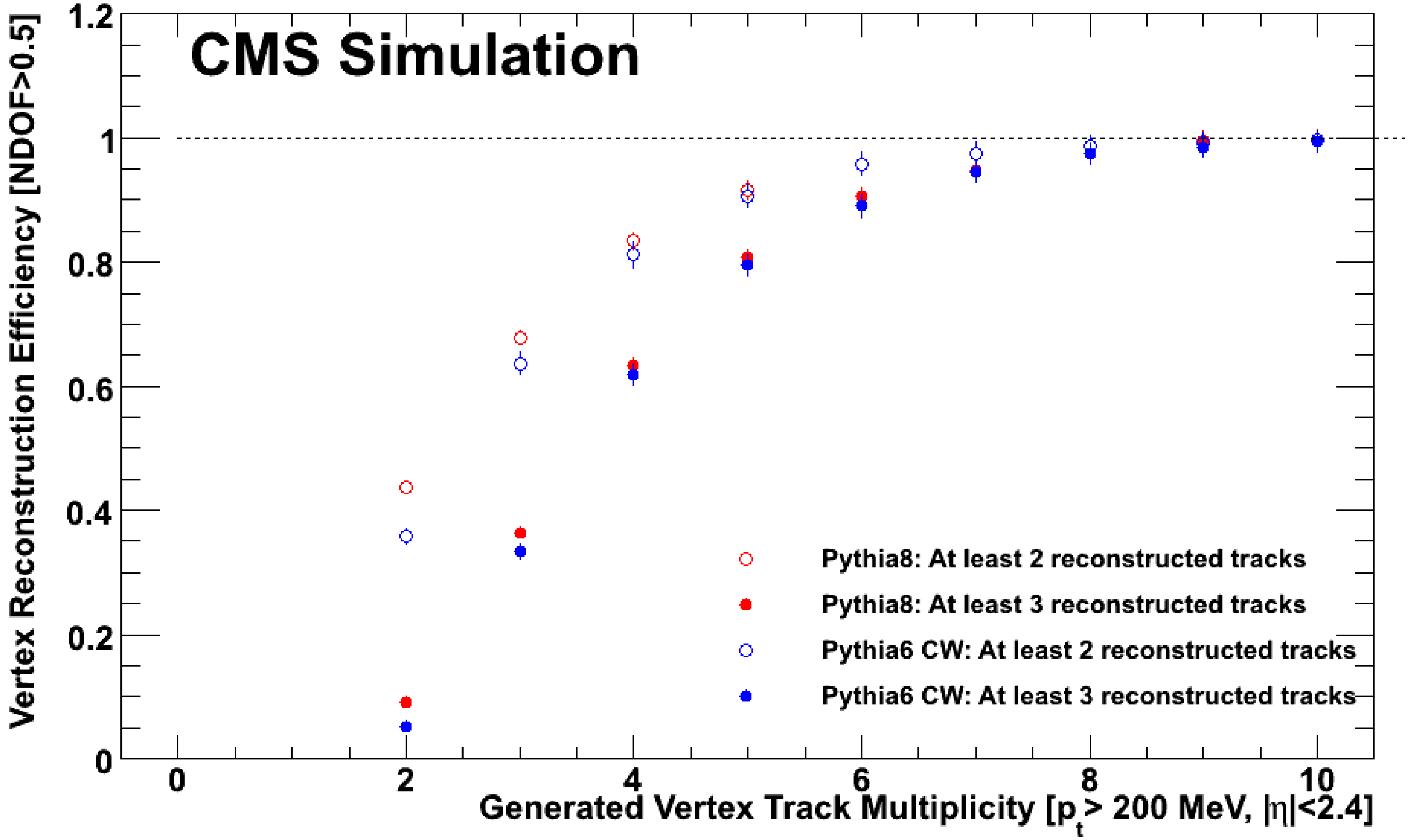
How many pile-up events are there?



We studied events with 0-8 pile-up events (non enough statistics to go further)

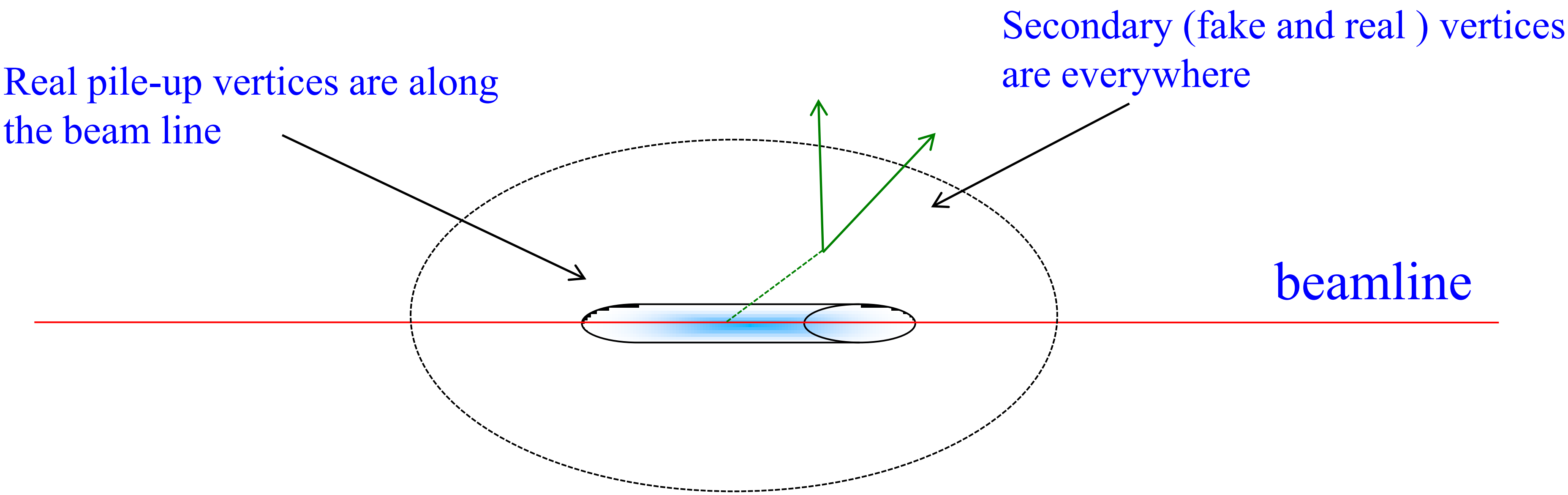
Vertex reconstruction

The goal of the analysis is to count the number of pile-up events as a function of luminosity. This means we need to count vertices.



Vertex requirements

Position along the beam line:



Quality cut:

At least 3 tracks with p_t>200 MeV in |eta|<2.4.

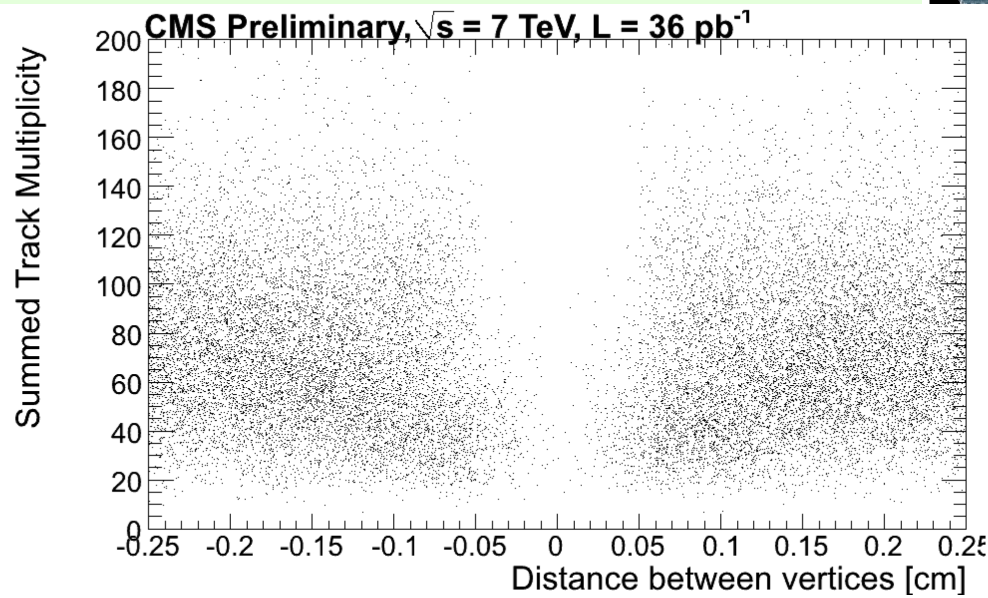
Each track should have at least 2 pixel hits and 5 strip hits

The vertex should pass an overall quality cut, NDOF>0.5

Vertex merging and secondary vertices

Vertex merging:

When two vertexes overlap they are merged into a single one.
This blind distance is ~ 0.06 cm

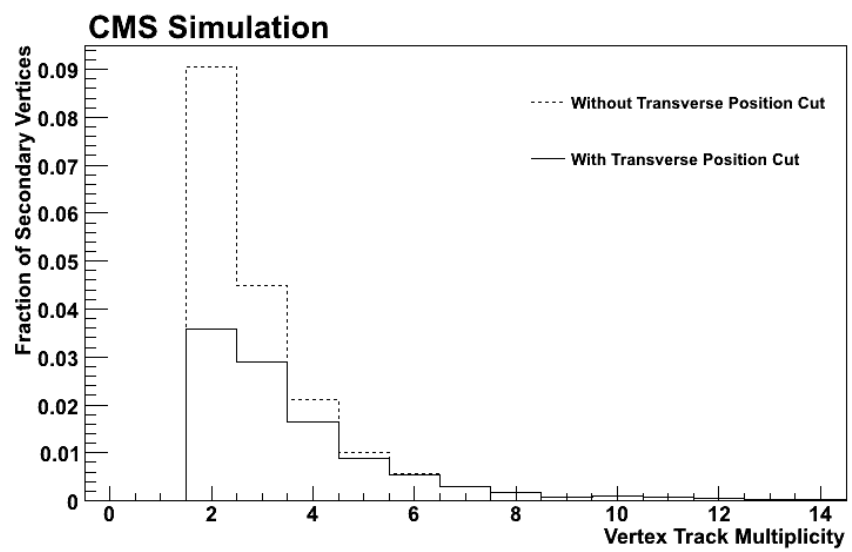


Secondary vertices:

1. Fakes from the reconstruction program
2. Real non prompt decay

Both reduced by the request on the transverse position

Most evident at low track multiplicity

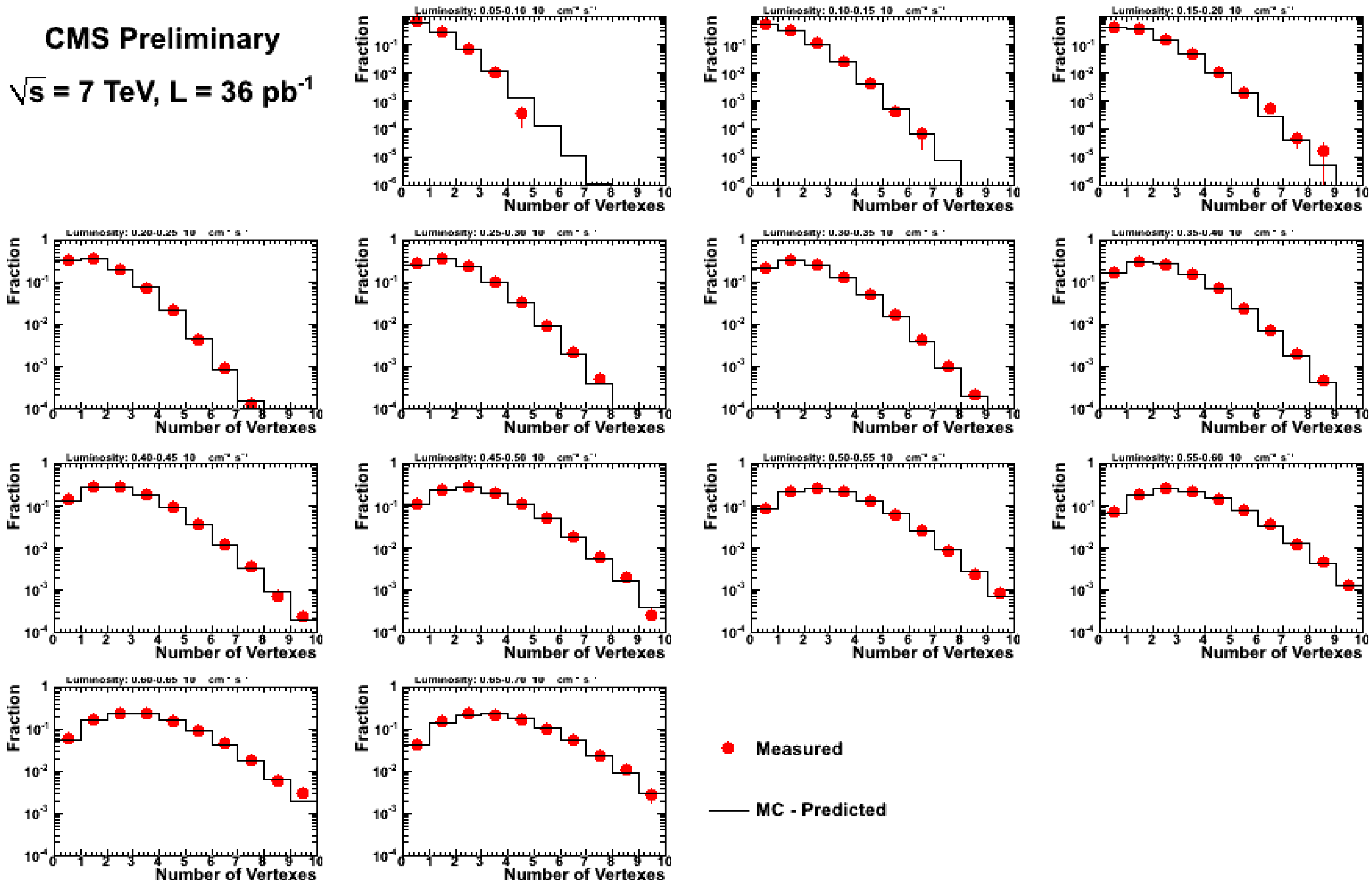


Simulation - I

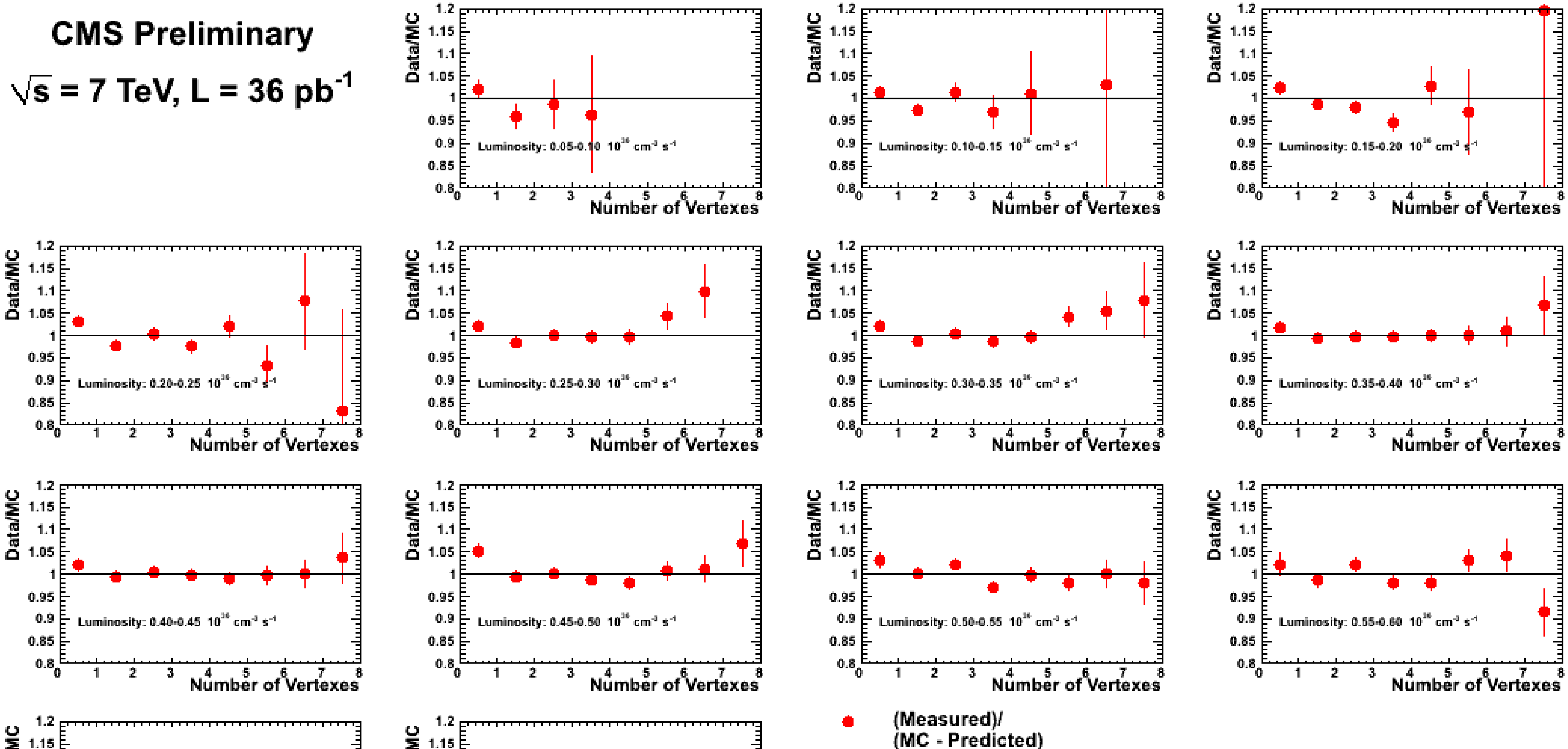
This analysis uses only the simulation of the vertex efficiency, which does not depend on the specific physics model

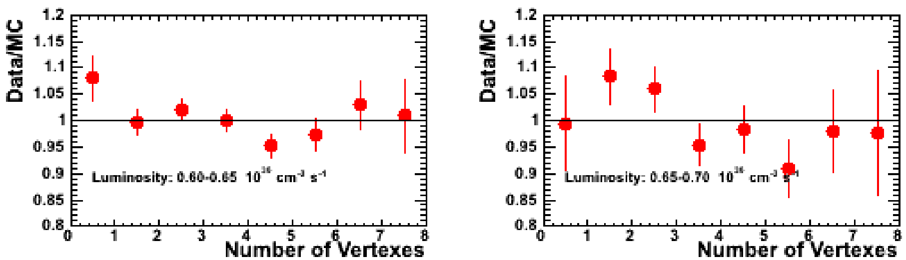
1) Data divided into 13 luminosity bins

2) In each luminosity bin we count the vertices



Simulation - II



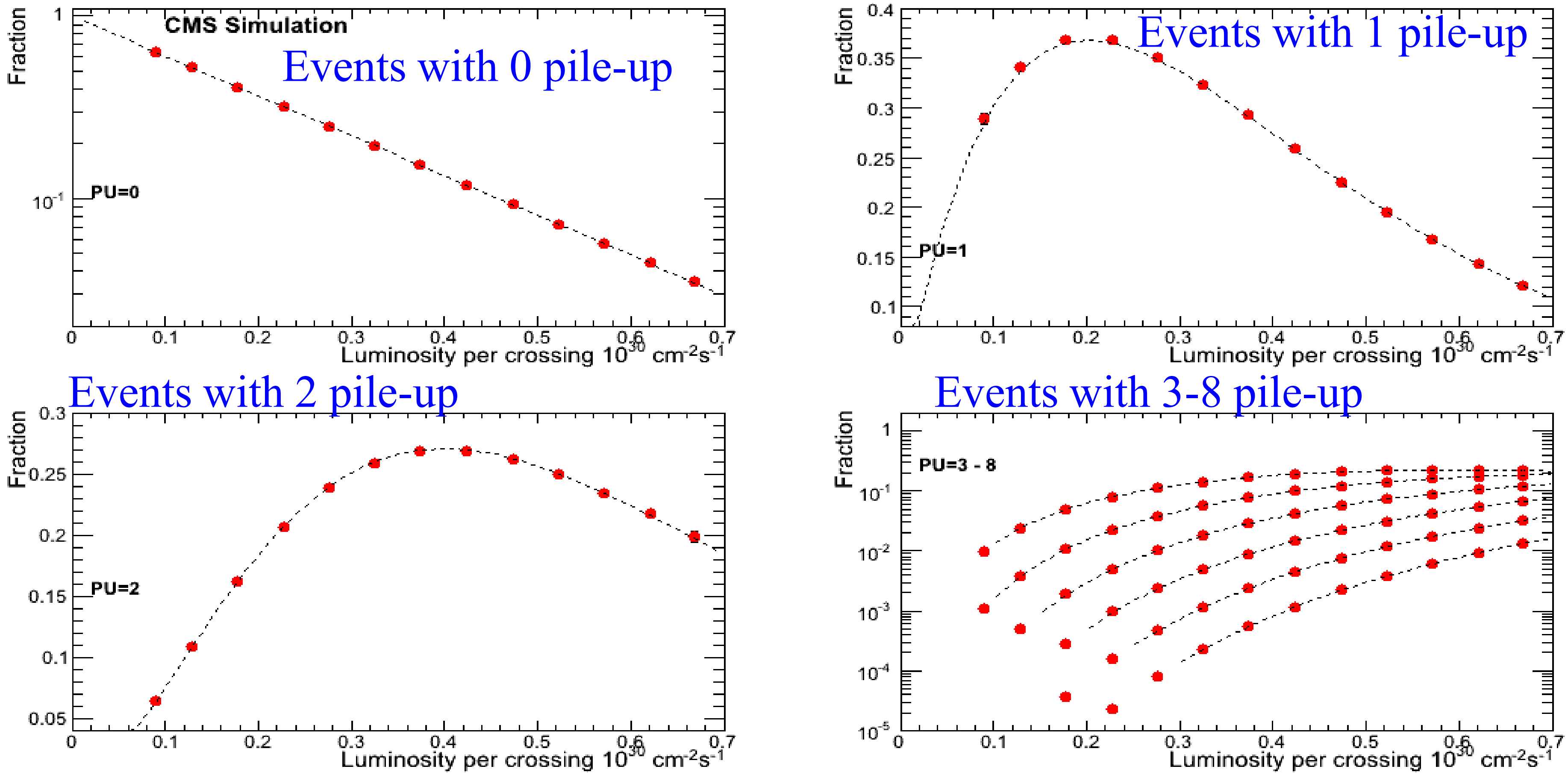


Ratio Data/MC very flat up to 8 pile-up events

Simulation- III: Does this idea work?

We have done the analysis using simulated events as real data:

1. We impose a Monte Carlo total inelastic cross section (64 mb)
2. At generation the fraction of events with 3 tracks, |eta|<2.4: 56.3 mb (88%)

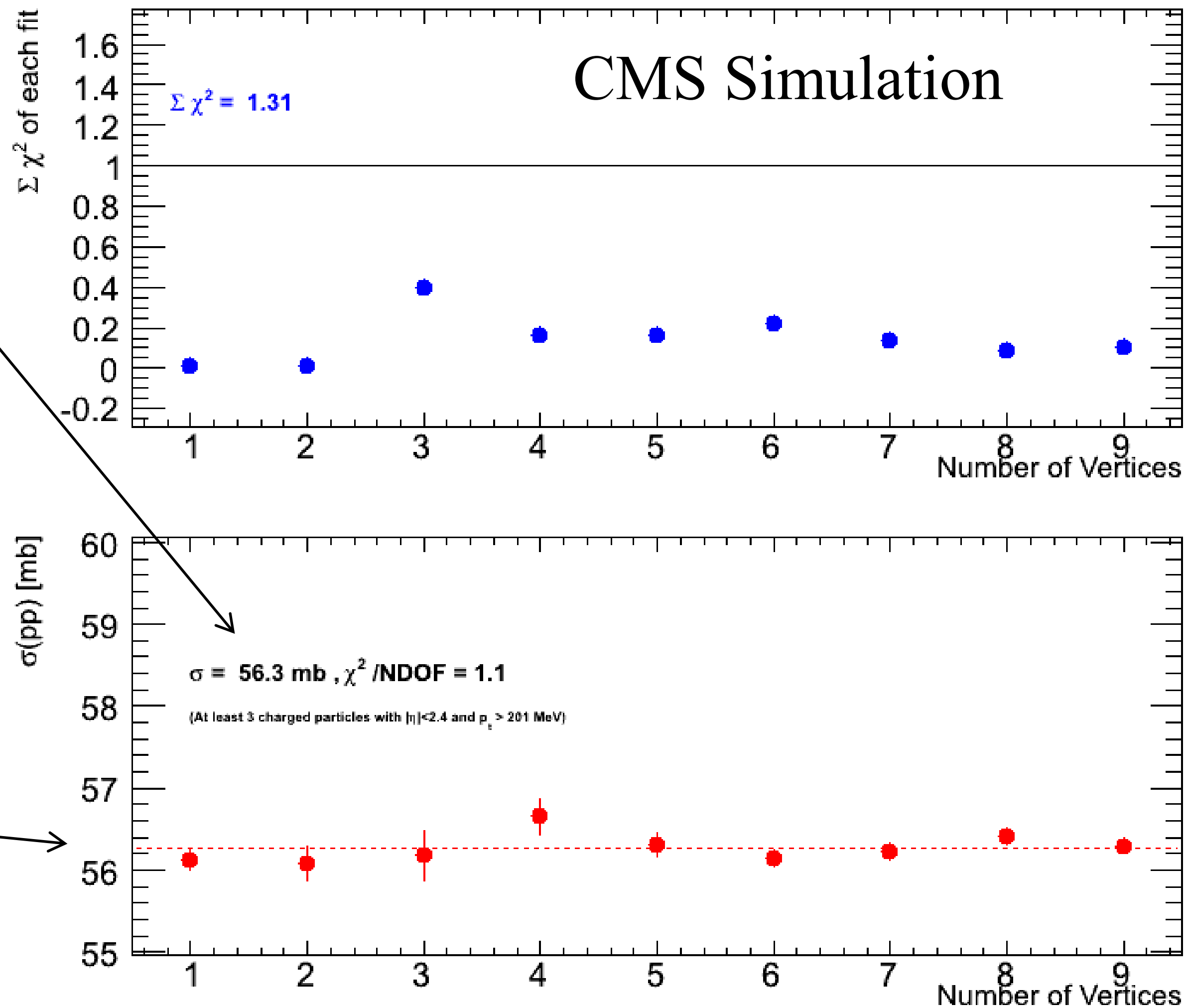


Simulation – IV: Results

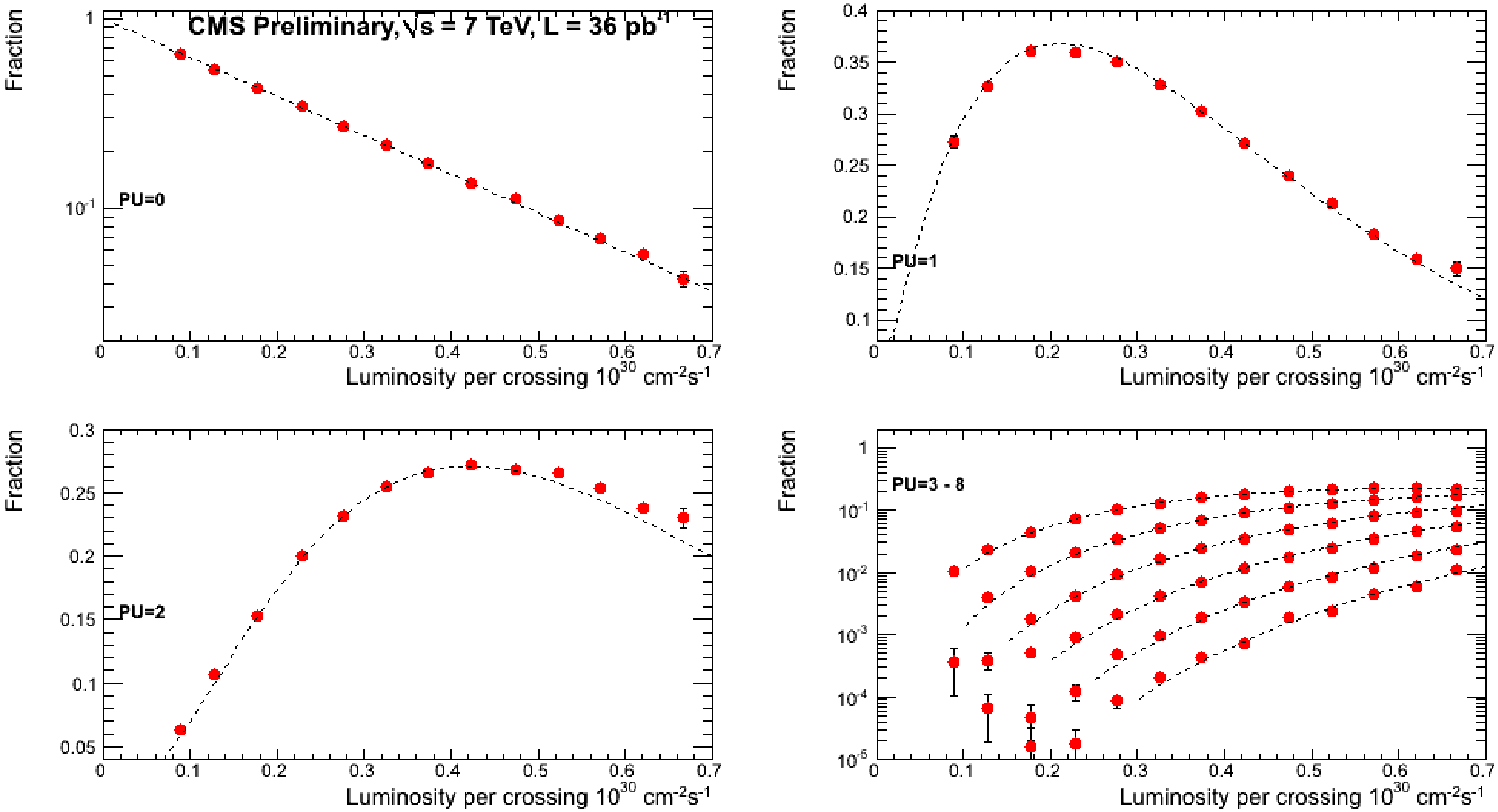
Result from fit: 56.3 mb

(At generation: 56.3…)

Fit from different pile-up numbers

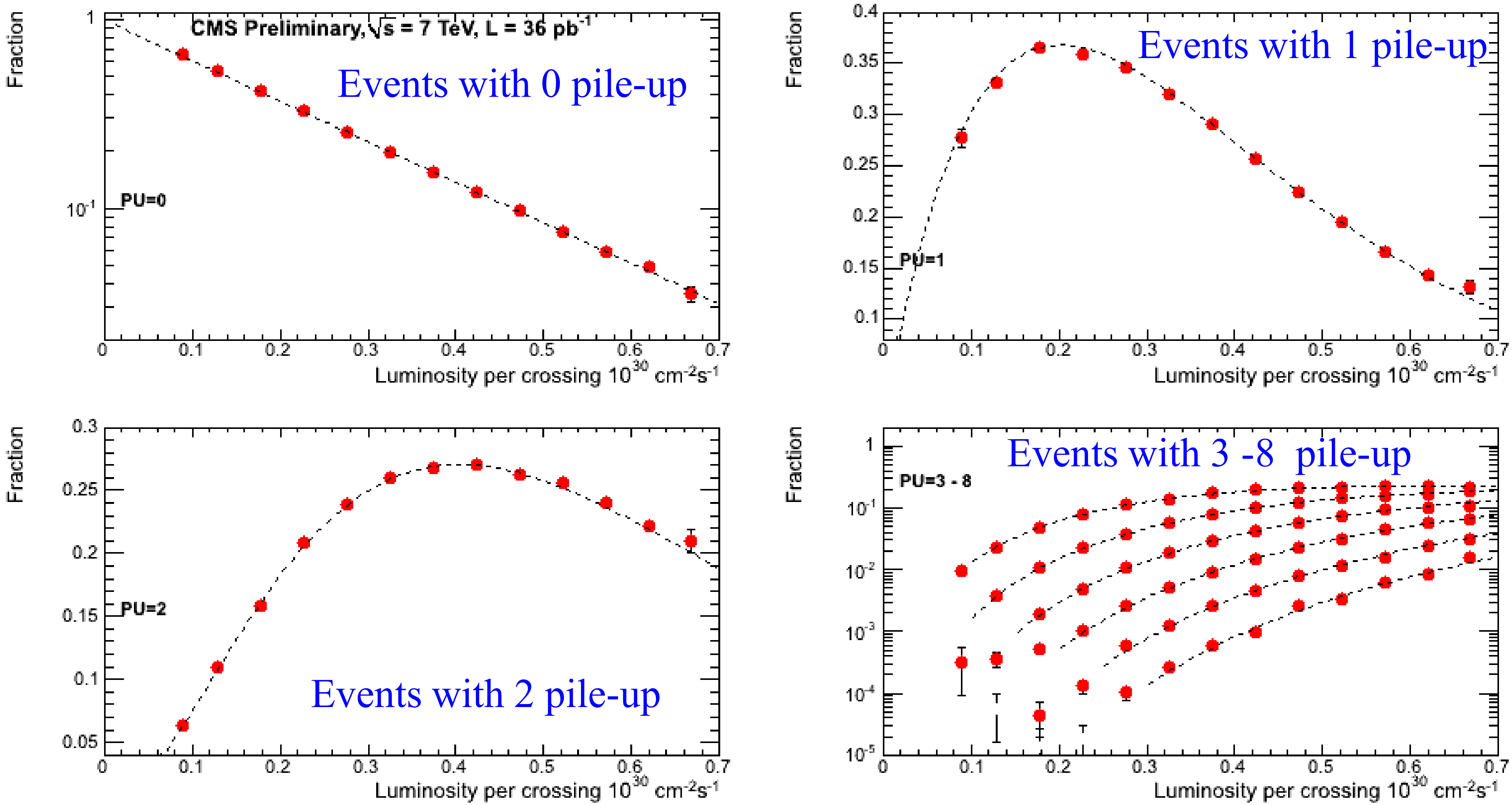


Data: uncorrected distributions



Given the very good CMS vertex efficiency, good fits even without corrections

Data: corrected distributions



Fitted Cross Section

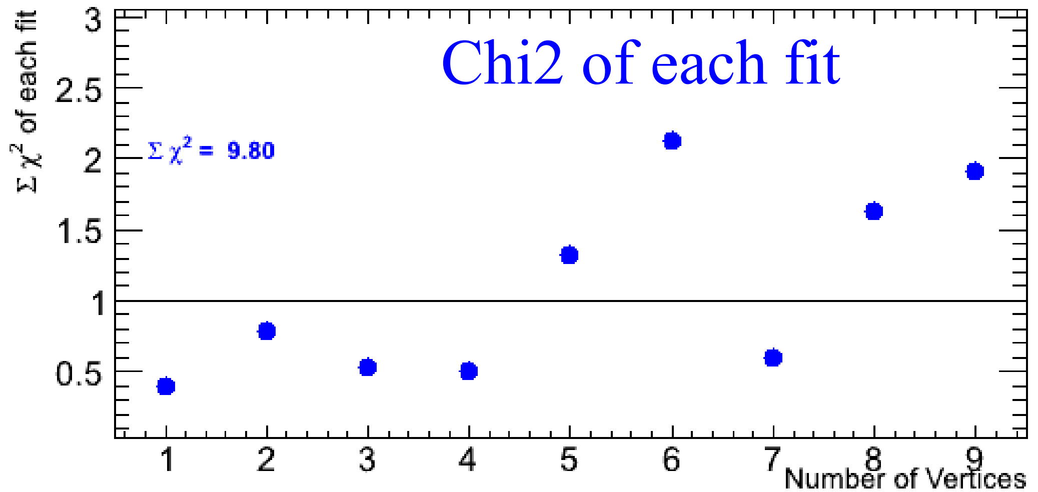
Each fit provides an estimate of the cross section.

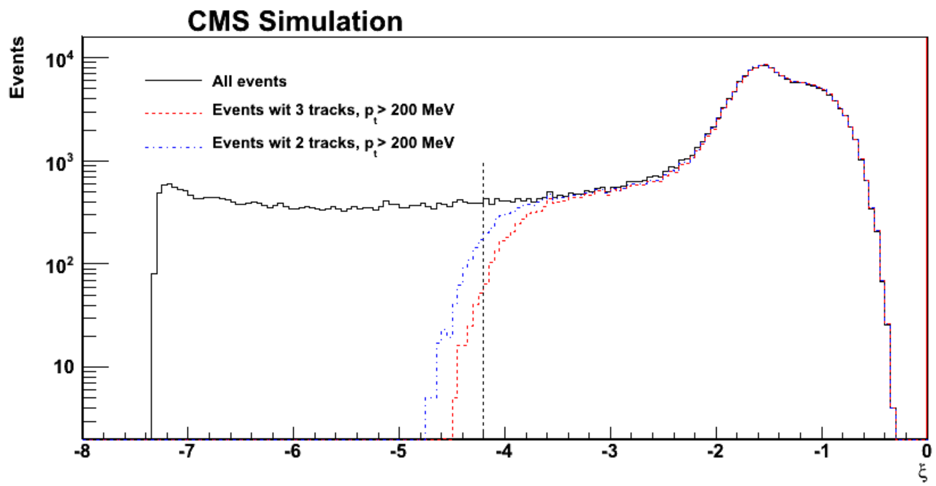
The fit to these 9 values gives the final value:

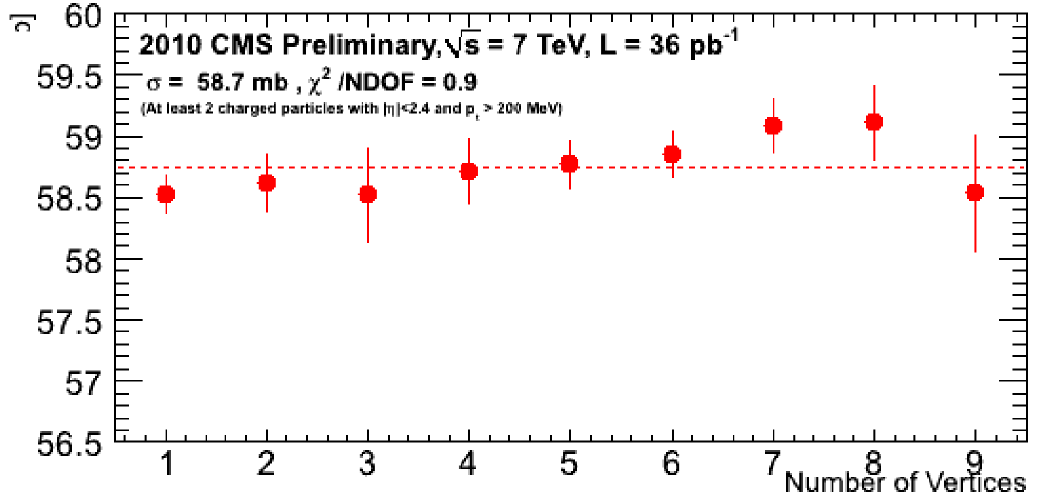
$\sigma(pp) = 58.7$ mb

(2 charged particles with p_t>200 MeV in |eta|< 2.4)

ξ ($\xi = M_x^2/s$) interval: $> 6 * 10^{-5}$







Main Systematic Errors

Luminosity:

The CMS luminosity value is known with a precision of 4% : $\Delta\sigma = 2.4$ mb

Analysis:

Use a different set of primary events (single mu or double electron): $\Delta\sigma = 0.9$ mb

Change the fit limit by 0.05: $\Delta\sigma = 0.2$ mb

Change the minimum distance between vertices (0.06 – 0.2 cm): $\Delta\sigma = 0.3$ mb

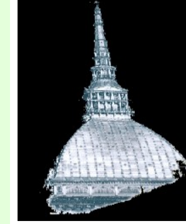
Change the vertex quality requirement (NDOF (0.5 – 2) & Trans. cut, & number of minimum tracks at reconstruction) : $\Delta\sigma = 1.0$ mb

Use an analytic method instead of a MC: $\Delta\sigma = 1.4$ mb

$$\sigma(pp) = 58.7 \pm 2.0\ (\text{Syst}) \pm 2.4\ (\text{Lum})\ \text{mb}$$

(2 charged particles with pt>200 MeV in |eta|< 2.4)

Additional measurements



Using the same technique we measured 4 different cross sections:

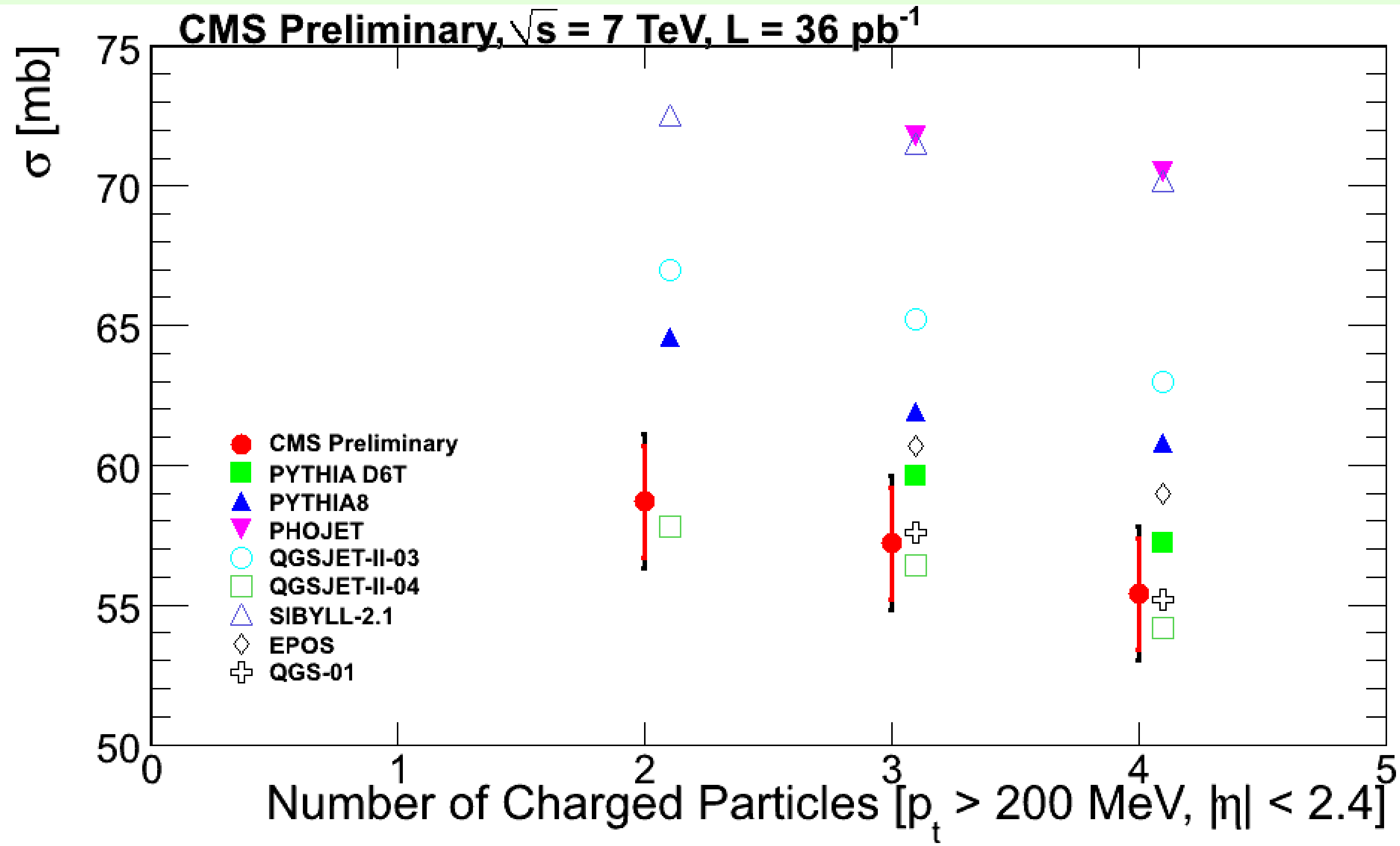
- 2 charged particles with pt>200 MeV in |eta|< 2.4
  $\sigma(pp) = 58.7 \pm 2.0$ (Syst) $\pm$ 2.4 (Lum) mb

- 3 charged particles with pt>200 MeV in |eta|< 2.4
  $\sigma(pp) = 57.2 \pm 2.0$ (Syst) $\pm$ 2.4 (Lum) mb

- 4 charged particles with pt>200 MeV in |eta|< 2.4
  $\sigma(pp) = 55.4 \pm 2.0$ (Syst) $\pm$ 2.4 (Lum) mb

- 3 particles with pt>200 MeV in |eta|< 2.4
  $\sigma(pp) = 59.7 \pm 2.0$ (Syst) $\pm$ 2.4 (Lum) mb

Comparison with Models and Extrapolation to σ_{inel} (pp)



We compared to several models and we defined a range of values for the extrapolation factor to go from the measured values to the total cross inelastic cross section:

$$\sigma_{inel}\ (pp) = 63 - 72\ \text{mb}$$

Comparison with Models - I

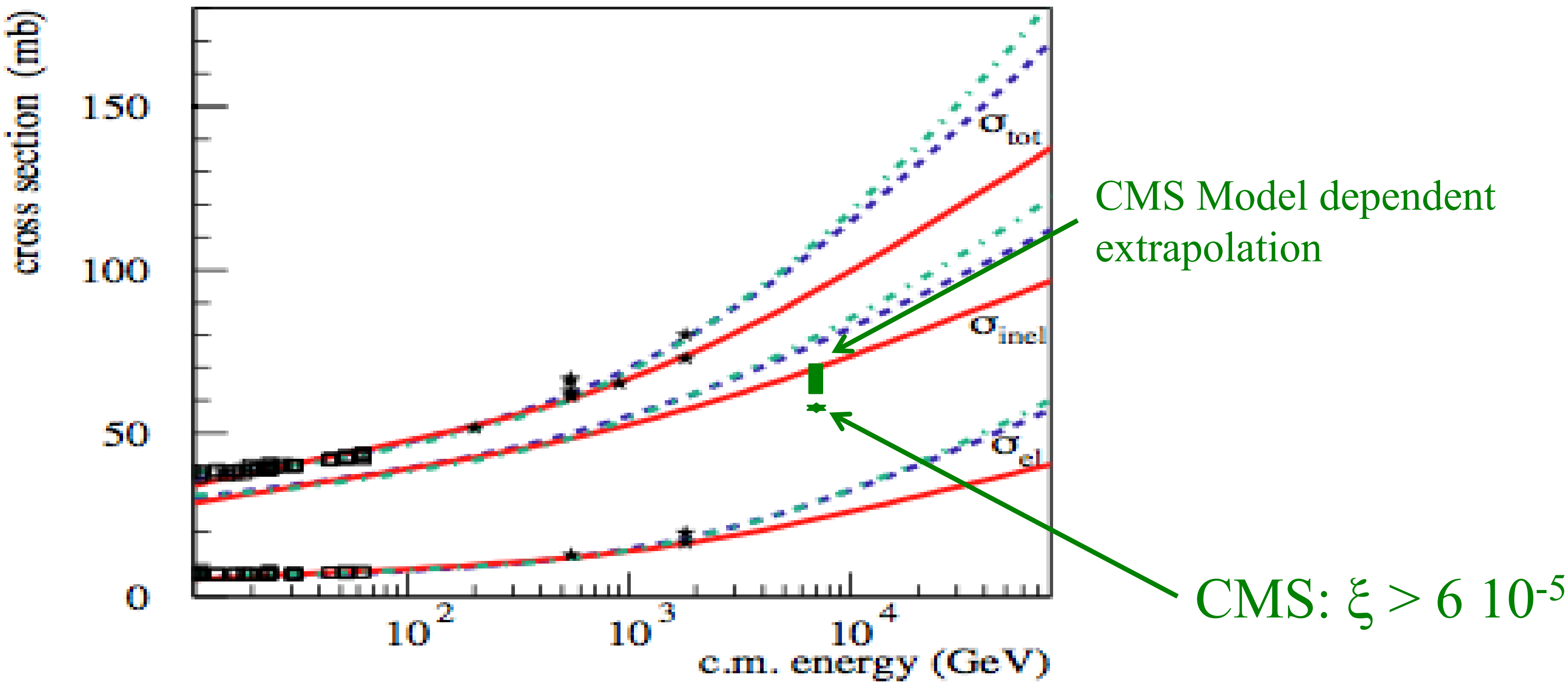
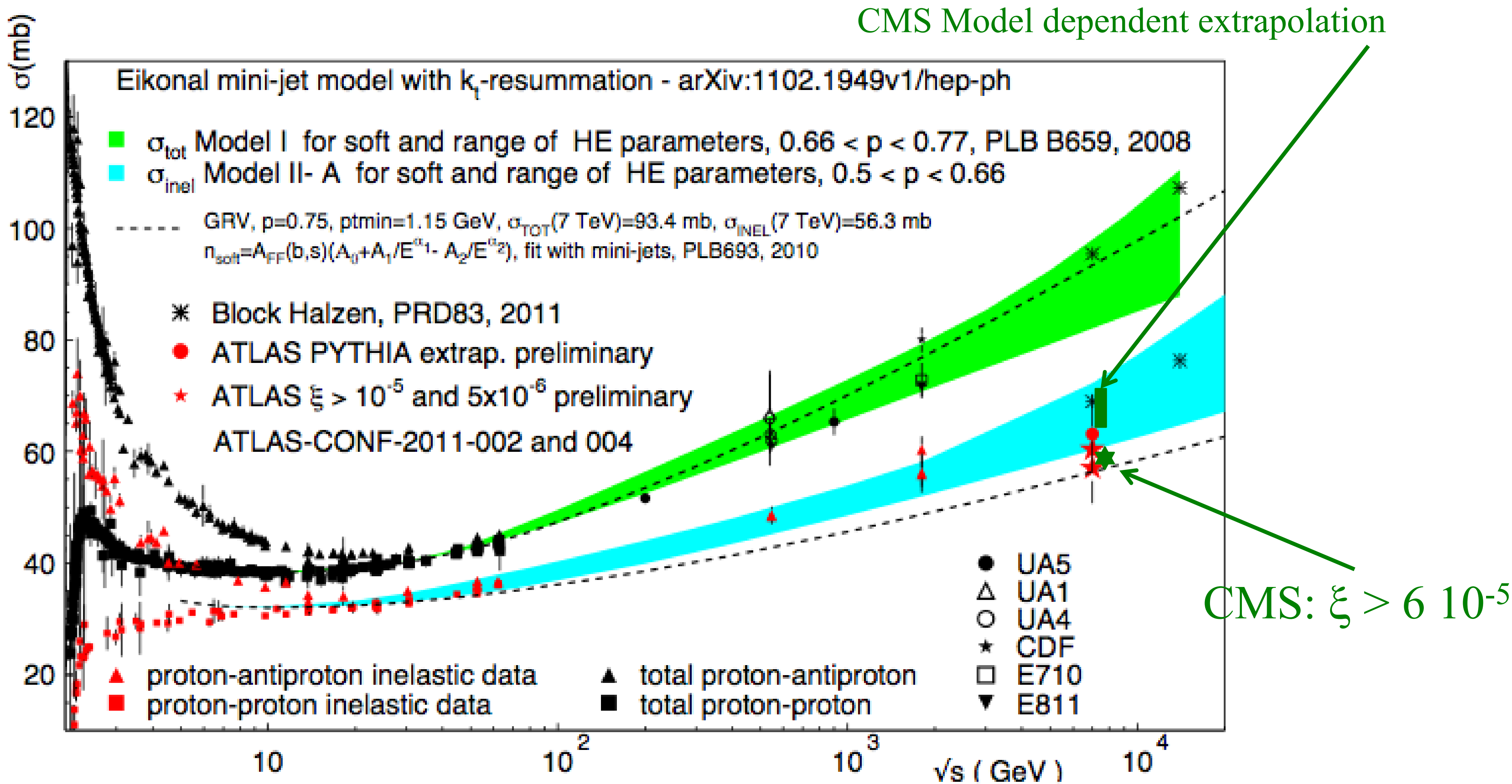
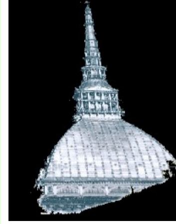


Figure 1: Model predictions for total, elastic, and inelastic proton-proton cross sections: QGSJET-II-4 - solid, QGSJET-II-3 - dashed, and SIBYLL - dot-dashed. The compilation of data is from Ref. [17].

Comparison with Models, Results - II





Summary

We have developed a new method to measure the inelastic pp cross section

The value for 2 tracks, |eta|<2.4 and p_t>200 MeV ($\xi > 6\ 10^{-5}$) is:

$$\sigma = 58.7 \pm 2\ (\mathrm{Sys}) \pm 2.4\ (\mathrm{Lum})\ \mathrm{mb}$$

Systematic checks show that the largest uncertainty derives from the luminosity measurement.

Using Monte Carlo - driven extrapolations we obtain a value for the total inelastic pp cross section in the range:

$$\sigma_{inel}\ (pp) = 68 \pm 2\ (\mathrm{Sys}) \pm 2.4\ (\mathrm{Lum}) \pm 4\ (\mathrm{Extrap})\ \mathrm{mb}$$